Titanium-salt Flocculation and its Sludge Resource Recovery to Photocatalyst for Advanced Water Treatment

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By

Yousef Okour

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Certificate

I certify that this thesis has not already been submitted for any degree and is not being submitted as part of a candidature for any other degree.

I also certify that the thesis has been written by me. Any help that I have received with all information sources and literature used are indicated in the thesis.

Signature of Candidate

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Yousef Okour

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Table of Contents

Chapter 3

Materials and Methods

Chapter 4

Characterisation of Titanium Tetrachloride ($TiCl_4$) and Titanium Sulfate ($Ti(SO_4)_2$) flocculation in Wastewater Treatment

Chapter 5

Preparation and Characterisation of Titania Produced from Ti-Flocculated sludge

Chapter 6

Inorganic-Organic Dual Coagulants using Ti-salt and Chitosan for Effective Ti-salt Flocculation

Chapter 7

Seasonal Variation in Properties of Titania Photocatalysts Produced from Ti-salt Flocculated Sludge

Chapter 8

Preparation, Characterisation and Photocatalytic Activity of Thiourea Doped Titanate Nanotubes

Chapter 9

Solar light Photocatalytic Activity of Pollutant-Specific Titania in Degradation of the POPs

Chapter 10

Conclusions and Recommendations

List of Abbreviations and Symbols

Abbreviations

APHA	: American Public Health Association
AW-TN	: Acid washed-titanate nanotubes
BET	: Brunauer, Emmett and Teller
BTSE	: Biologically treated sewage effluent
COD	: Chemical oxygen demand
DCA	: Dichloro acetic acid
DI	: Deionised water
DOC	: Dissolved organic carbon
DW	: Drinking water
E1	: Estrone
E2	: 17β-estradiol
E2Ac	: β-estradiol 17-acetate
E3	: Estriol
EC50	: Effective concentration of a 50% loss of bioluminescence obtained after 15 min exposure
EDCs	: Endocrine distrusting chemicals
EE2	: 17α-ethinylestradiol
GC/FID	: Gas chromatograph with a flame ionisation detector
HA	: Humic acids
HPSEC	: High pressure size exclusion chromatography
HRTEM	: High-resolution transmission electron microscopy
log K_{ow}	: Octanol-water partition coefficient
LC	: Median lethal concentration
M&M	: Metsulfurn methyl
MQ	: Milli-Q
MW	: Molecular weight
NOM	: Natural organic matter
PCBs	: Dioxin-like polychlorinated biphenyls
PCDDs	: Polychlorinated dibenzo-p-dioxins

PCDFs	: Polychlorinated dibenzo-furans
pH_{ZPC}	: pH at zero point charge
Pka	: Acidity
POPs	: Persistent organic pollutants
PPCPs	: Pharmaceutical and personal care products
RhB	: Rhodamine B
rpm	: Round per minute
SBR	: Sequencing batch reactor
SEM/EDX	: Scanning electron microscopy and energy dispersive X-ray
SUVA	: Specific ultraviolet absorbance
SW	: Sea water
SWW	: Synthetic wastewater
TD-TN	: Thiourea doped-titanate nanotubes
TEM	: Transmission electron microscopy
TN	: Titanate nanotubes
USEPA	: United States Environmental Protection Agency
UV	: Ultraviolet
UV-254	: Ultra-violet at 254 nanometre absorption
v/v	: Volume ratio
w/v	: Weight to volume ratio
WW	: Wastewater
WW-TN	: Water washed-titanate nanotubes
XPS	: X-ray photoelectron spectroscopy
XRD	: X-ray diffraction

Symbols

A	: Accepter
B	: Full width at half max in radians
c	: Concentration of substrate (mg/L)
c_0	: Initial concentration of substrate (mg/L)
d	: Donor
e	: Electron
h	: Hour
h^+	: Positively charged hole
hν	: Photonic energy
I	: Irradiation intensity (mW cm^{-2})
k	: Apparent reaction rate constant (min^{-1})
K	: Langmuir adsorption coefficient (L mg^{-1})
min	: Minute
$O_2^{\bullet-}$	: Superoxide anions
$OH^{\bullet}$	: Hydroxide radical
R^2	: Correlation coefficient
t	: Thickness of an crystallite (nm)
V	: Volume (mL or L)
θ_B	: Bragg angle of the 2θ peak
λ	: X-ray wavelength (nm)

List of Tables

List of Figures

Abstract

This research embraces several objectives targeting different aspects of environmental concern in terms of wastewater flocculation, sludge disposal and removing of persistent organic pollutants from water and wastewater. The production of a large amount of sludge using coagulants of iron (Fe) and aluminium (Al) salts that needs disposal is considered as the most costly and environmentally problematic challenge in wastewater treatment. Titanium (Ti) salt used as an alternative coagulant reduces the cost of sludge disposal and protects the environment by producing titania photocatalyst from the incinerated sludge. However, titania photocatalyst is only a UV light responsive and its pollutant-specific photocatalytic degradation for various organic pollutants has not being examined. Thus, the main objectives of this study are:

1. Increase the efficiency of Ti-salt flocculation in terms of organic matter removal and sludge reduction by using a natural polymer of chitosan as a coagulant-aid.
2. Trace the seasonal variation in the characteristics of Ti-salt flocculation and as prepared-titania photocatalyst.
3. Produce pollutant-specific titania photocatalyst by synthesising titanate nanotubes (TN) and thiourea (CSN_2H_4) doped-titanate nanotubes (TD-TN) photocatalysts through the hydrothermal treatment of as prepared-titania.
4. Investigate the pollutant-specific photocatalytic activity of as prepared-titania and the synthesised titania photocatalysts in photodegrading of organic pollutant of gaseous acetaldehyde, humic acid (HA), dichloroacetic acid (DCA), rhodamine B (RhB), metsulfuron methyl (M&M) and phenol under UV, visible and solar light irradiation.

5. Then, select the best pollutant-specific titania for removing of 16 micropollutants of pharmaceutical and personal care products (PPCPs) and endocrine disrupting chemicals (EDCs) in water.

Our findings indicated that Ti-salt flocculation exhibited more reduction in turbidity, and colour of wastewater compared with Fe- and Al-salt flocculation. In addition, the use of chitosan was very efficient for enhancing the performance of Ti-salt flocculation. Ti-salt and chitosan flocculation improved significantly the turbidity and organic removal of wastewater up to 85%, considerably reduced the optimum dose of Ti-salt from 25 mg/L to less than 5 mg/L, solved the low pH of Ti-salt flocculation, and achieved in 40% reduction of Ti-salt flocculation sludge. The change in wastewater characteristics in different seasons has a negligible influence in the characteristics of Ti-salt flocculation and as prepared-titania. During the whole seasons, the turbidity and orthophosphate removal of Ti-salt flocculation were varied from 70 to 90% and 96 to 99%, respectively. As prepared-titania photocatalyst exhibited predominant anatase structure, high BET surface area and insignificant change in its photocatalytic activity. The photocatalytic degradation of HA and RhB was varied from 85 to 90% and 91 to 98%, respectively. The modified TD-TN photocatalyst exhibited superior photocatalytic activity than as prepared-titania and TN photocatalysts for photocatalytic degradation of the tested organic pollutants under visible and solar light. TD-TN photocatalyst was selected to photodegrade a set of 16 micropollutants of PPCPS and EDCs in water, exhibited a complete photocatalytic degradation of 7 micropollutants at TD-NT concentration of 50 mg/L. The photocatalytic degradation significantly increased with increasing in TD-NT concentration and complete photocatalytic degradation was achieved at TD-NT concentration of 500 mg/L after 90 minutes. The high photocatalysis activity of TD-NT in decomposing persistent organic pollutants and micropollutants would increase the attention to use of Ti-salt coagulant and titania photocatalyst as alternatives in water and wastewater treatment.